Depositional and Facies Controls on Infiltrated/Inherited Clay Coatings: Unayzah Sandstones, Saudi Arabia*

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Search and Discovery Article #50459 (2011)
Posted August 29, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011

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Abstract

Clay coatings on detrital quartz grains inhibit precipitation of burial diagenetic quartz overgrowths and help preserve porosity and permeability in Unayzah sandstones. These clay coatings are physically-emplaced, not neoformed (authigenic) clay coats such as fibrous illite or radial chlorite. Understanding the depositional and facies controls on these clay coatings and their relationship is necessary to predict reservoir quality in the Unayzah sands.

Grain coatings are found in all depositional environments that have been investigated (Eolian, fluvial, lacustrine, glacial diamictite, and estuarine depositional settings). These coatings are especially abundant in sands associated with clayey paleosols. They are presently composed of illite and/or chlorite, but these may have had precursor clay minerals prior to burial diagenesis. The relative amounts of clay coatings depend not only on the type of depositional environment, but also on the stratigraphic unit within which the environment resides. This is interpreted to be a function of changing paleoclimates during deposition of the Unayzah.

Moreover, this study shows that the presence of these clay coatings is grain-size dependent. For a given depositional setting there is a direct relation between the mean grain size of sandstones and the average percentage of coated grains. The finer the grains, the more clay coatings (~ 90%); and the coarser the grains, the fewer grain coatings (~ 50%) in the samples.

Chlorite is the dominant clay coating in eolian settings, especially associated with coarser eolian grains in dune and sand sheet sub-environments recognized on the upper part of Unayzah (Unayzah A). Also, in this unit, grains deposited in fluvial settings may be coated with illite or chlorite. In estuarine and fluvially dominated estuarine deposits (of the BKC), illite is the dominant clay coating.

Both chlorites and illites are present (with different percentages) in the relatively finer grains deposited in floodplain/playa and interdune/distal sheet flood sub environments (of Unayzah A and B units).

To summarize, we suggest that depositional environment, paleoclimate, and grain size are all factors in the genesis of clay coatings. Some clay coatings formed in-place by pedogenesis (soil-forming processes), and “inherited” clay coatings on grains transported by eolian (and fluvial) processes may have originally formed in pedogenic environments.

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Depositional and Facies Controls on Infiltrated / Inherited Clay Coatings: Unayzah Sandstones; Saudi Arabia

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AAPG-Houston-April 13, 2011

Challenge

Anomalous porosity preserved in deep reservoirs (Permo-Carboniferous sandstones)

Reasons?
What kind of depositional environments?

Business Impact

Once predicted, it reduces exploration risks & helps reservoir development

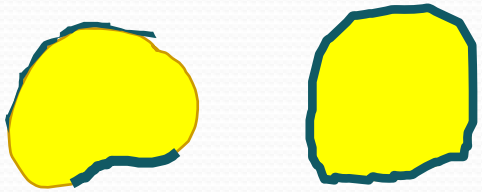
Outline

- Types & Definitions
- Methodology
- Stratigraphy
- Depositional Facies
- Petrographic Data
- Reservoir Quality
- Conclusions

Types & Definitions

Inherited Clay Coats:

Clay coatings that form on detrital grains prior to their deposition.



partially or completely coat the surfaces.

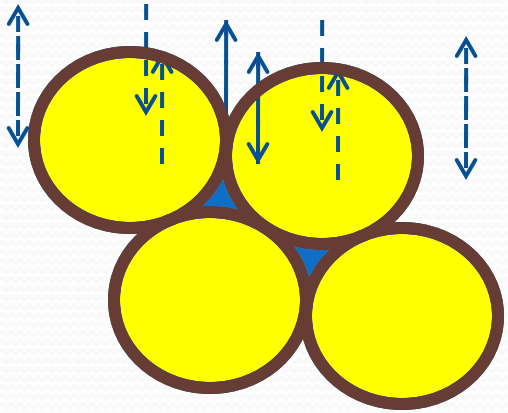
tangential (surface matting) clays

thick in depressions (concavities) thinner over bumps (convexties),

common at grain contacts

Infiltrated / Pedogenic Clay Coats:

Clay coatings that form on detrital grains after their deposition.



Percolation of ground water

clays concentrated in water films around detrital grains and formed coats when the grains dried.

Identification of Clay Types

	Criteria	Detrital Clays (early)		Authigenic Neoformed Clays (early to late)
		Inherited	Pedogenic / Infiltrated	
Distribution criteria	Present at grain contacts	VC	R?	R
	Meniscus Bridges	X	VC	O
	Internal Layering	X	VC	O
	Geopetal Features	X	C	X
	Wide Variations in Thickness	VC	VC	R
	Abundance in Fine-Grained Beds	VC	R?	X
	Abundance Varies between Beds	VC	VC	O
	Close to burrow structures or roots	X	O	X
	Thicker in Grain Surface Depression	VC	X	X
	Invades Late-Stage Dissolution Pores	X	R?	C
	Abundance Related to Depositional Environment	C	C	R
Composition criteria	Mixed-Clay Mineral Assemblage	C	C	R

VC-Very Common C-Common O-Occasionally R-Rare X-Absent

(modified from Wilson 1992)

Methodology

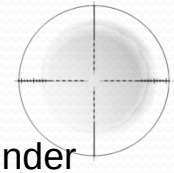
For ~ 250 samples

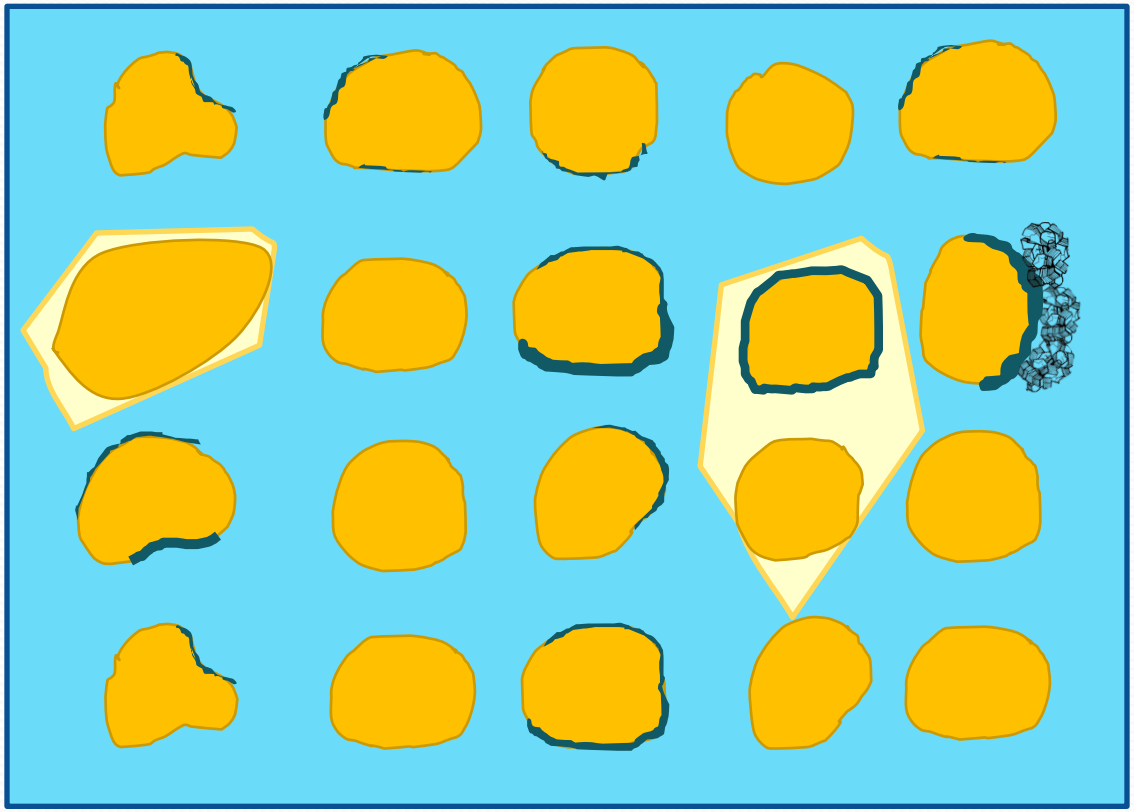
100 counts per thin section specifically to measure

grain size + clay coating %

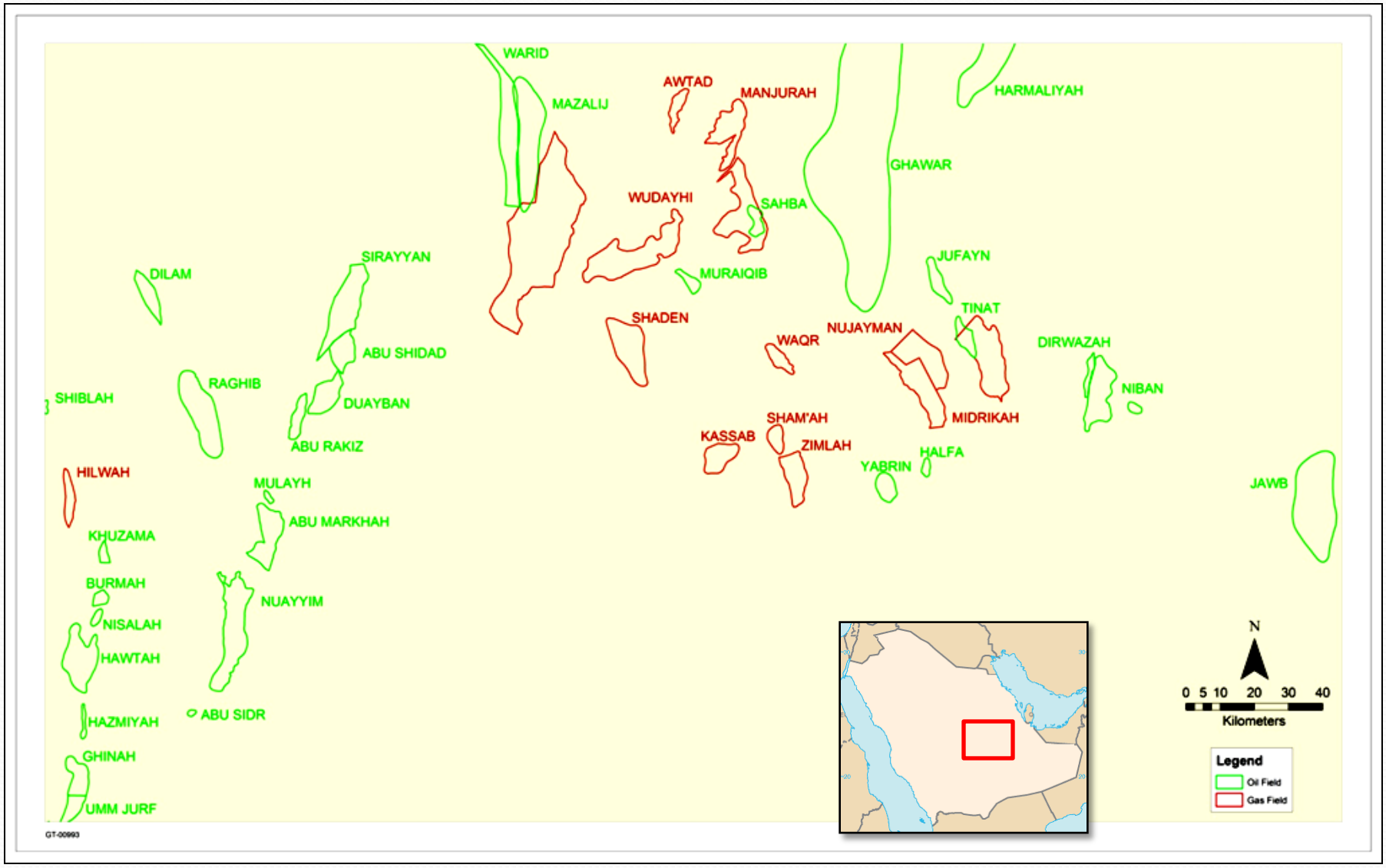
Five categories on these quartz grains:

1. With quartz overgrowth and no clay coat
2. With no quartz overgrowth and no clay coat
3. With clay coating
4. With clay coating under quartz overgrowth
5. With clay coating against clay-filled pore





Location


WARID
MAZALIJ
AWTAD
MANJURAH
HARMALIYAH
GHAWAR
WUDAYHI
SAHBA
SIRAYYAN
DILAM
JUFAYN
MURAIQIB
SHADEN
TINAT
NUJAYMAN
WAQR
DIRWAZAH
ABU SHIDAD
RAGHIB
NIBAN
SHIBLAH
DUAYBAN
SHAM'AH
MIDRIKAH
KASSAB
ZIMLAH
HALFA
ABU RAKIZ
YABRIN
HILWAH
MULAYH
JAWB
ABU MARKHAH
KHUZAMA
BURMAH
NUAYYIM
NISALAH
HAWTAH
HAZMIYAH
ABU SIDR
GHINAH
UMM JURF
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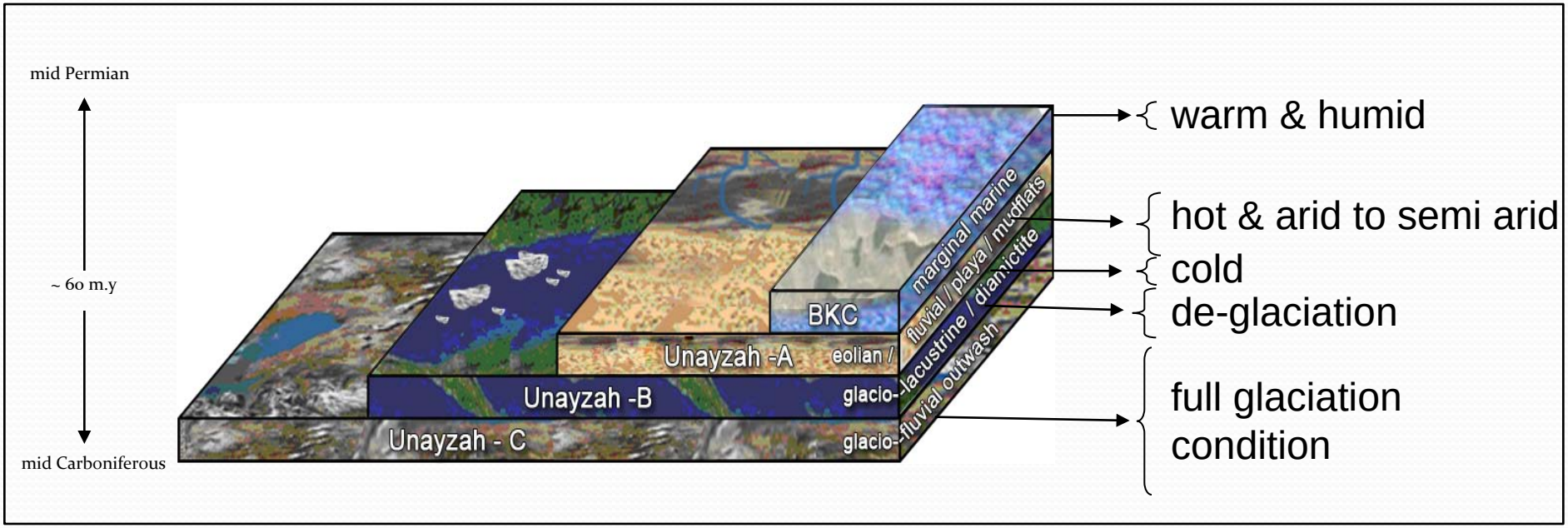
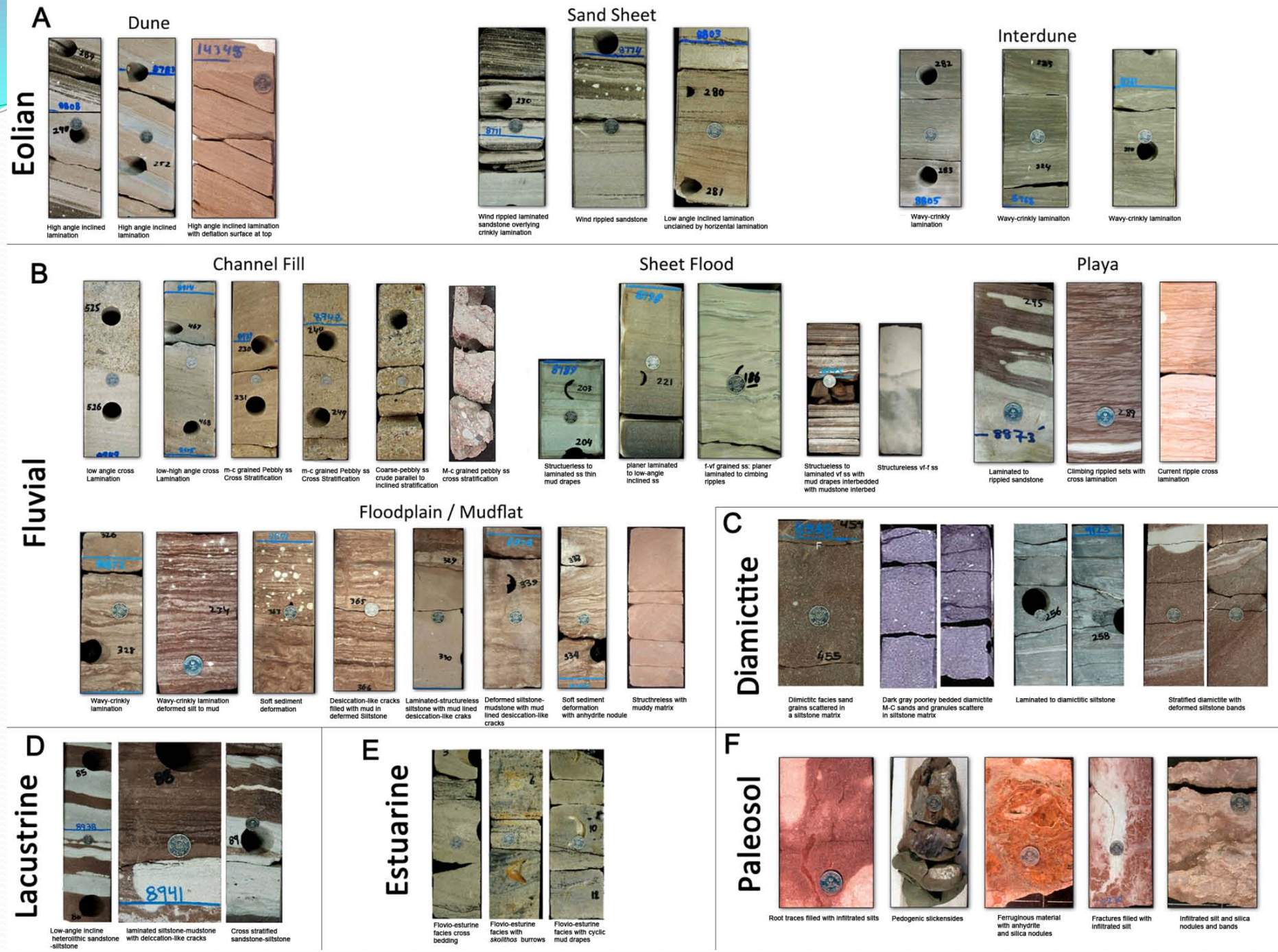
N
0 5 10 20 30 40
Kilometers
Legend
Oil Field
Gas Field

Permo-Carboniferous
Stratigraphy & Depositional Settings

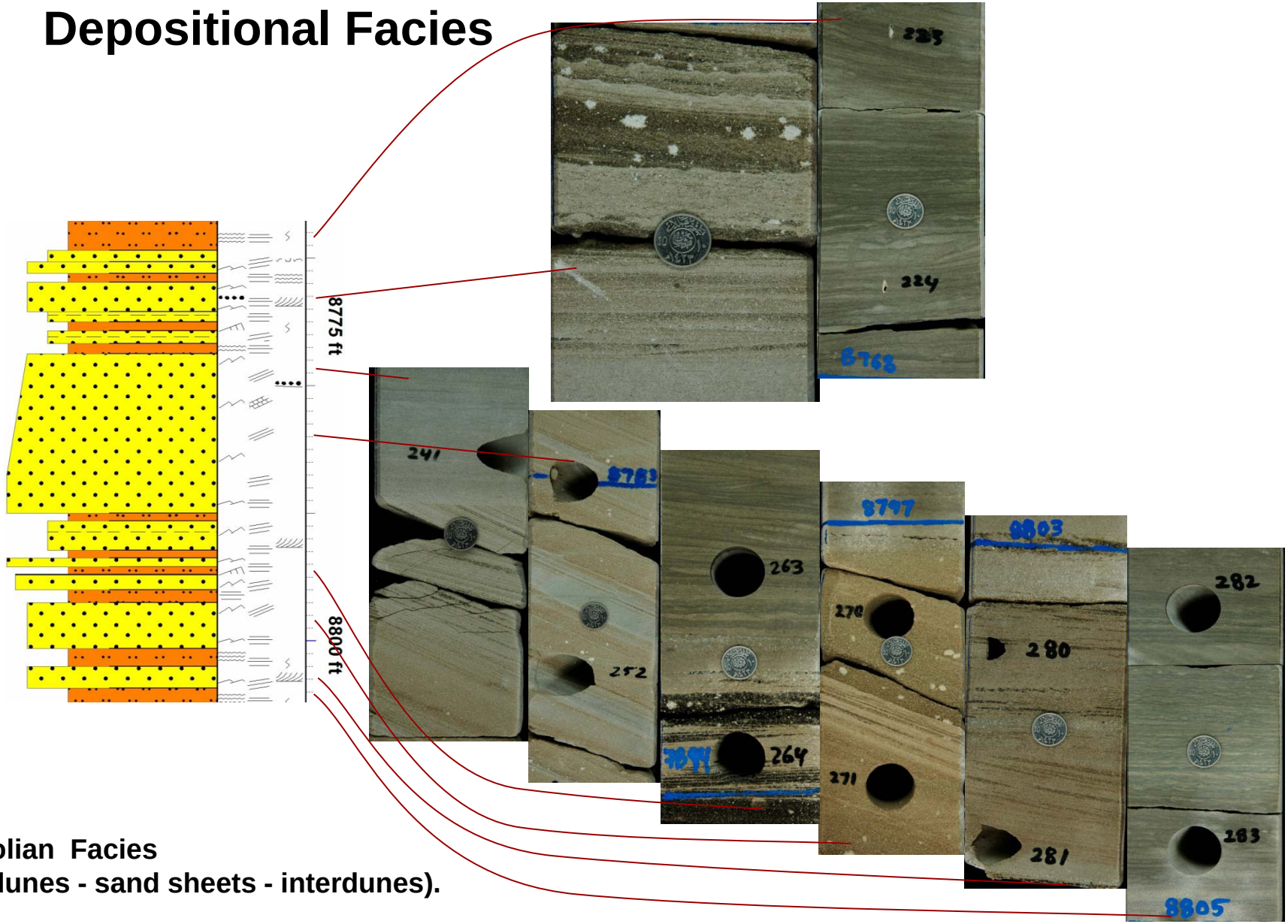


Eolian (dunes, sand sheets, interdunes)
Fluvial (channels, sheet floods, flood plains)

Lacustrine
Diamictite
Estuarine
Palaeosols


A
Eolian
Dune
High angle inclined lamination
High angle inclined lamination
High angle inclined lamination with deflation surface at top
Sand Sheet
Wind rippled laminated sandstone overlying crinkly lamination
Wind rippled sandstone
Low angle inclined lamination unclained by horizental lamination
Interdune
Wavy-crinkly lamination
Wavy-crinkly laminaiton
Wavy-crinkly laminaiton
B
Fluvial
Channel Fill
low angle cross Lamination
low-high angle cross Lamination
m-c grained Pebbly ss Cross Stratification
m-c grained Pebbly ss Cross Stratification
Coarse-pebbly ss crude parallel to inclined stratification
M-C grained pebbly ss cross stratification
Sheet Flood
Structuerless to laminated ss thin mud drapes
planer laminated to low-angle inclined ss
f-vf grained ss: planer laminated to cimbing ripples
Structueless to laminated vf ss with mud drapes interbedded with mudstone interbed
Structureless vf-f ss
Playa
Laminated to rippled sandstone
Climbing rippled sets with cross lamination
Current ripple cross lamination
Floodplain / Mudflat
Wavy-crinkly lamination
Wavy-crinkly lamination deformed silt to mud
Soft sediment deformation
Desiccation-like cracks filled with mud in deformed Siltstone
Laminated-structureless siltstone with mud lined desiccation-like craks
Deformed siltstone-mudstone with mud lined desiccation-like cracks
Soft sediment deformation with anhydrite nodule
Structhreless with muddy matrix
C
Diamictite
Diimictitc facies sand grains scattered in a siltstone matrix
Dark gray poorley bedded diamictite M-C sands and granules scattere in siltstone matrix
Laminated to diamictitic siltstone
Stratified diamictite with deformed siltstone bands
D
Lacustrine
Low-angle incline heteroilthic sandstone -siltstone
laminated siltstone-mudstone with deiccation-like cracks
Cross stratified sandstone-siltstone
E
Estuarine
Flovio-esturine facies cross bedding
Flovio-esturine facies with skolithos burrows
Flovio-esturine facies with cyclic mud drapes
F
Paleosol
Root traces filled with infiltrated silts
Pedogenic slickensides
Ferruginous material with anhydrite and silica nodules
Fractures filled with infiltrated silt
Infiltrated silt and silica nodules and bands

Depositional Facies

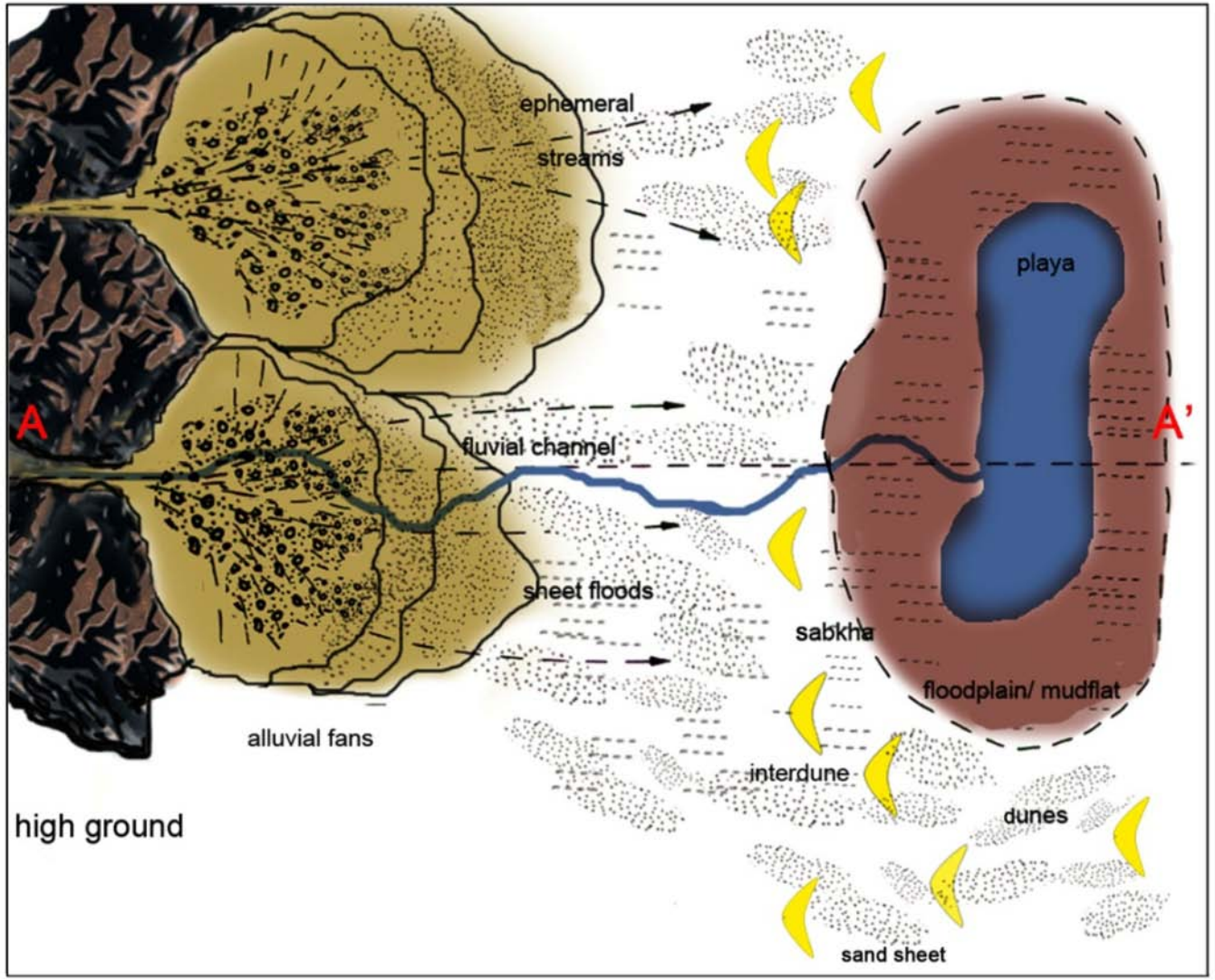


Eolian Facies
(dunes - sand sheets - interdunes).

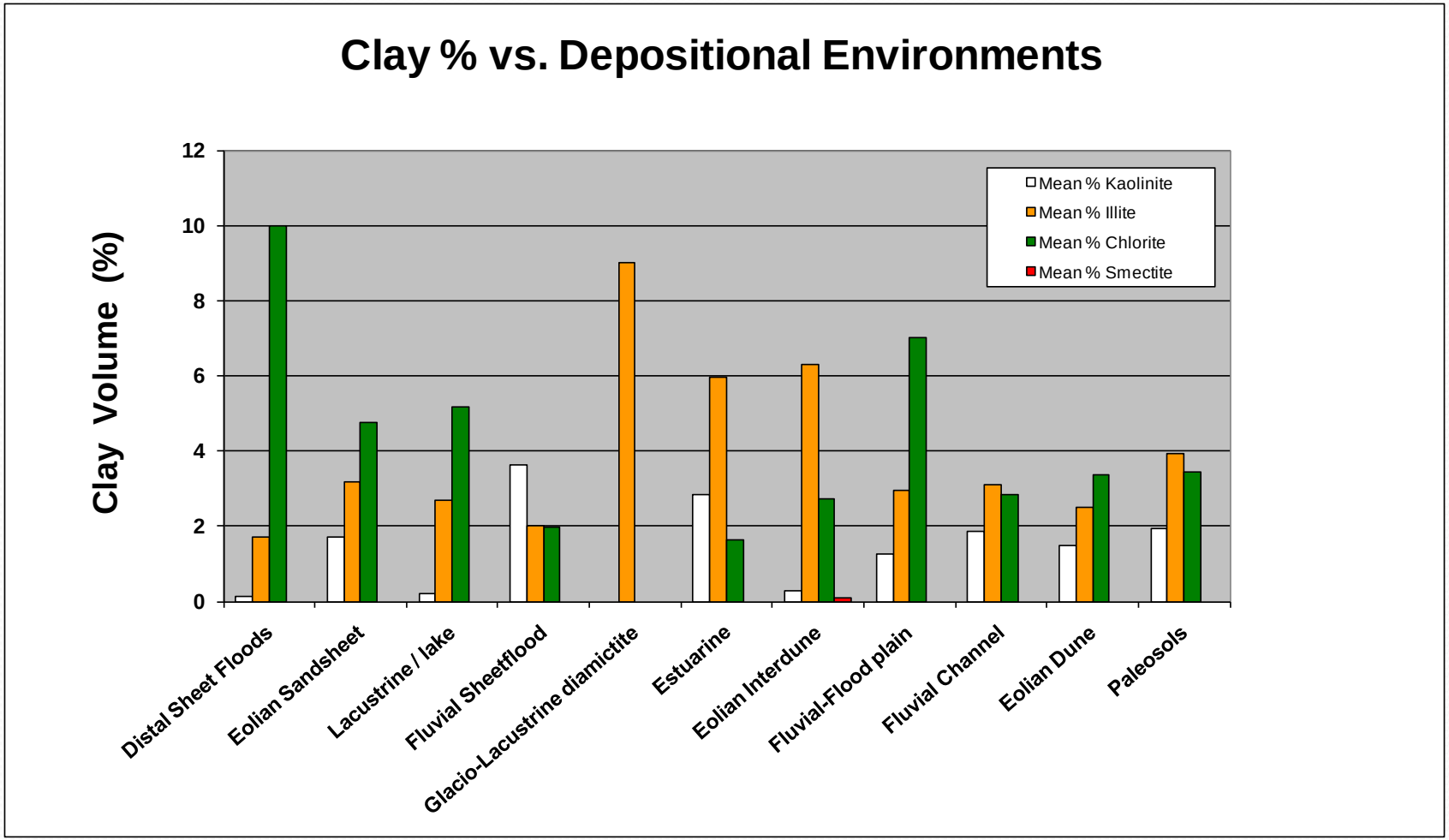
Depositional Facies

Fluvial Facies (channels - sheet floods – flood plains).

Depositional Facies Model:
Unayzah A



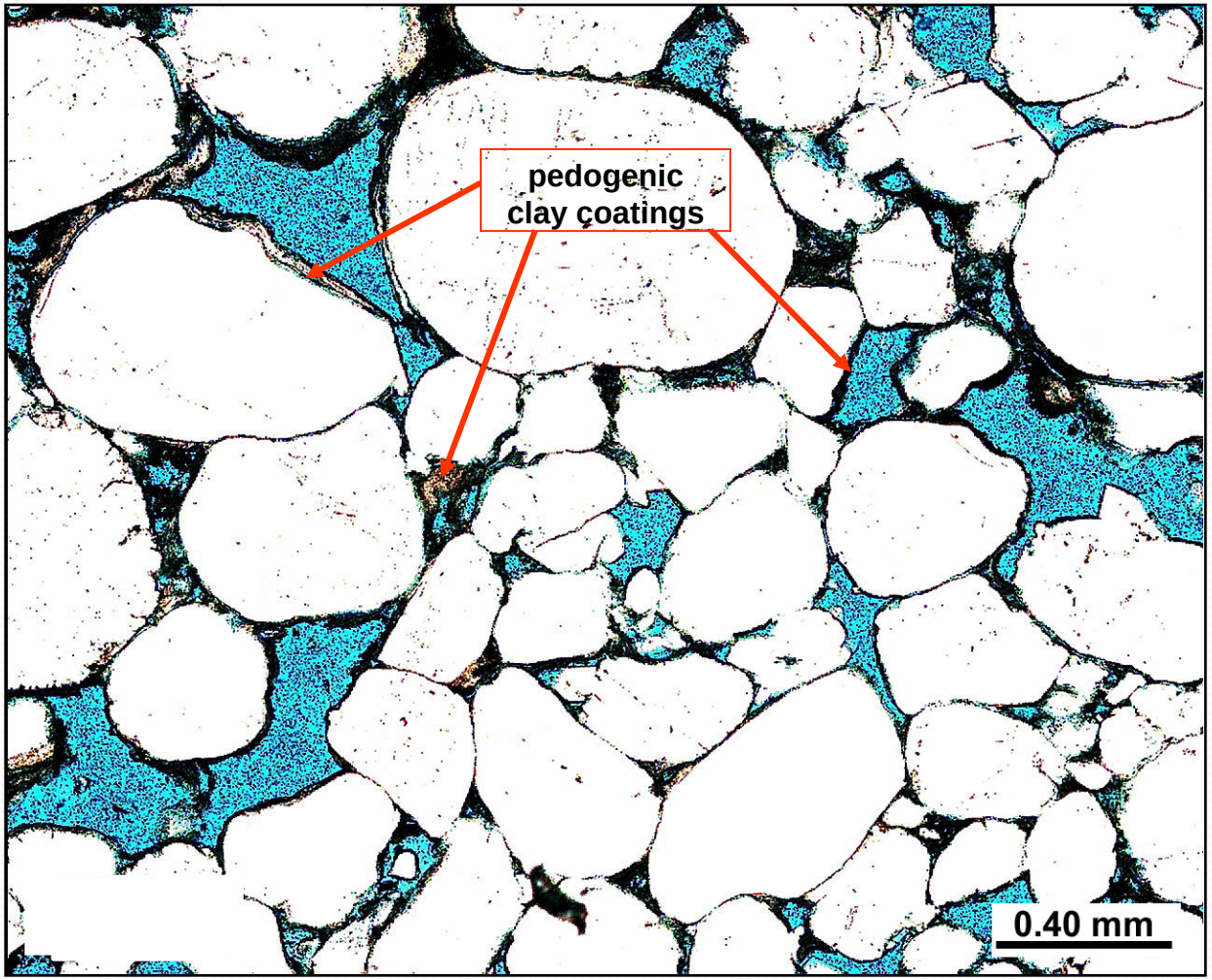
Petrographic and Diagenetic Observations



Pedogenic / Infiltrated Clay Type

Fluvio-Estuarine Facies

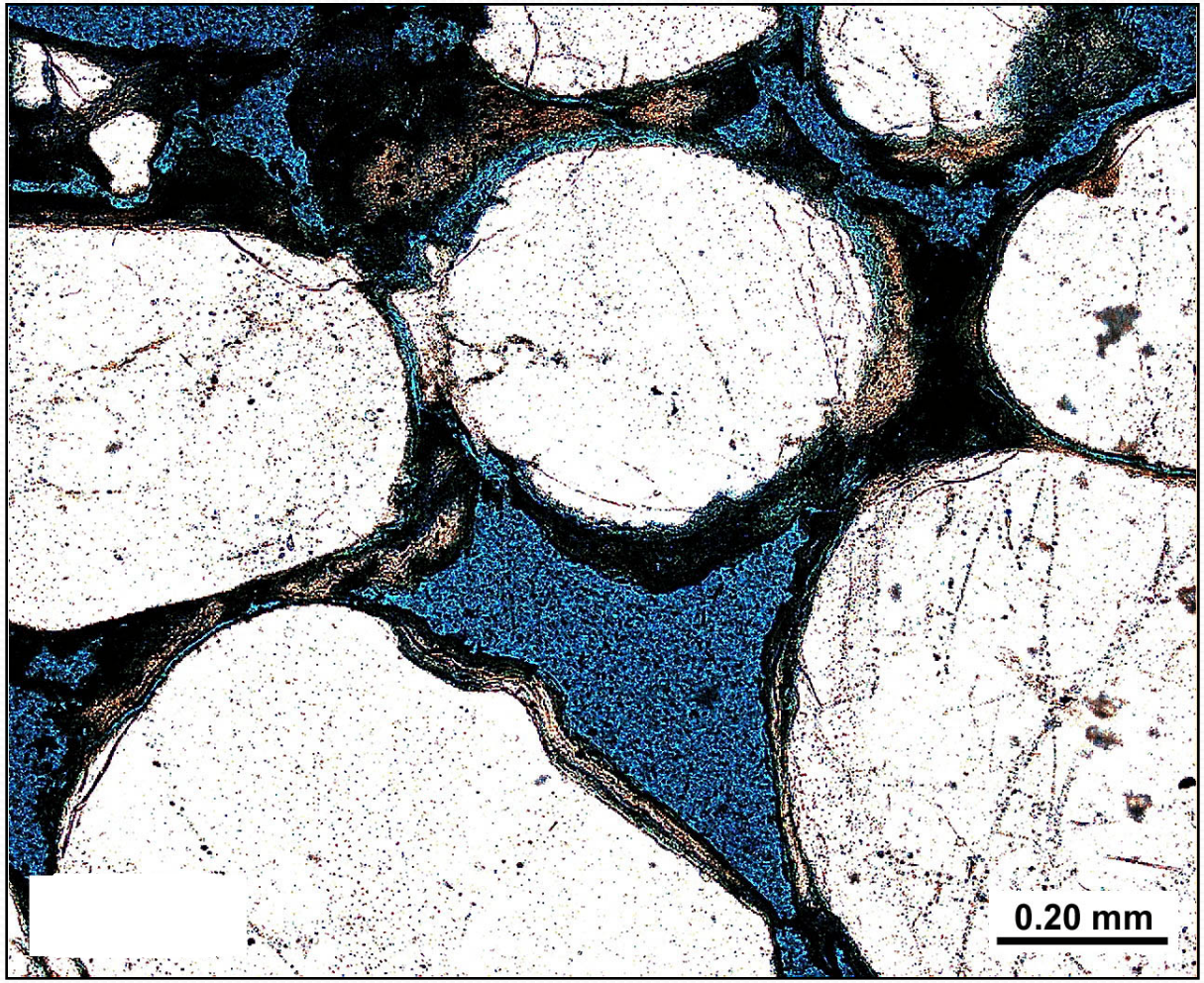
Basal Khuff Clastics (BKC)



Pedogenic / Infiltrated Clay Type

Fluvio-Estuarine Facies

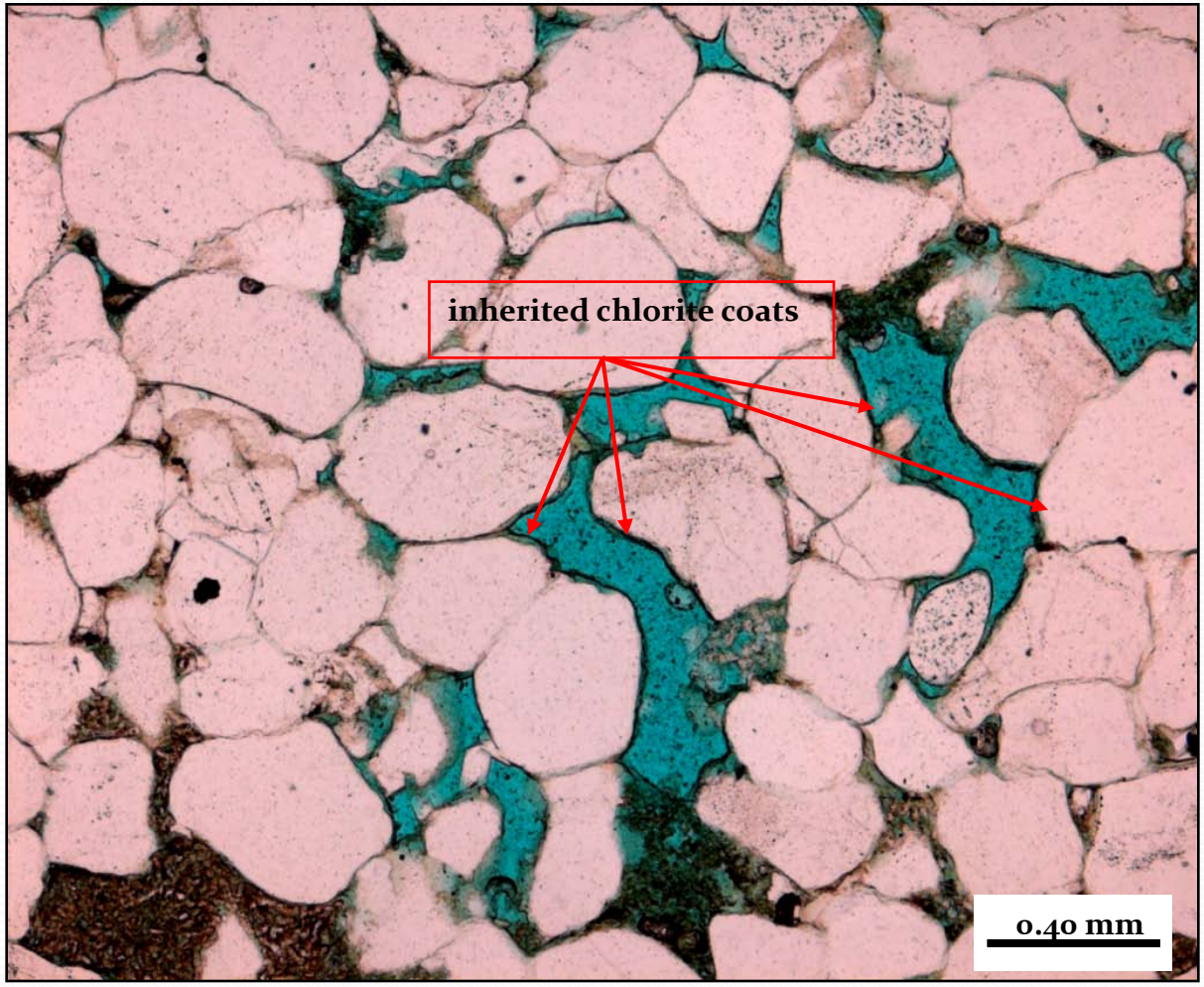
(BKC)



Inherited Clay Type

Eolian Depositional Environment
Sand Sheet Facies

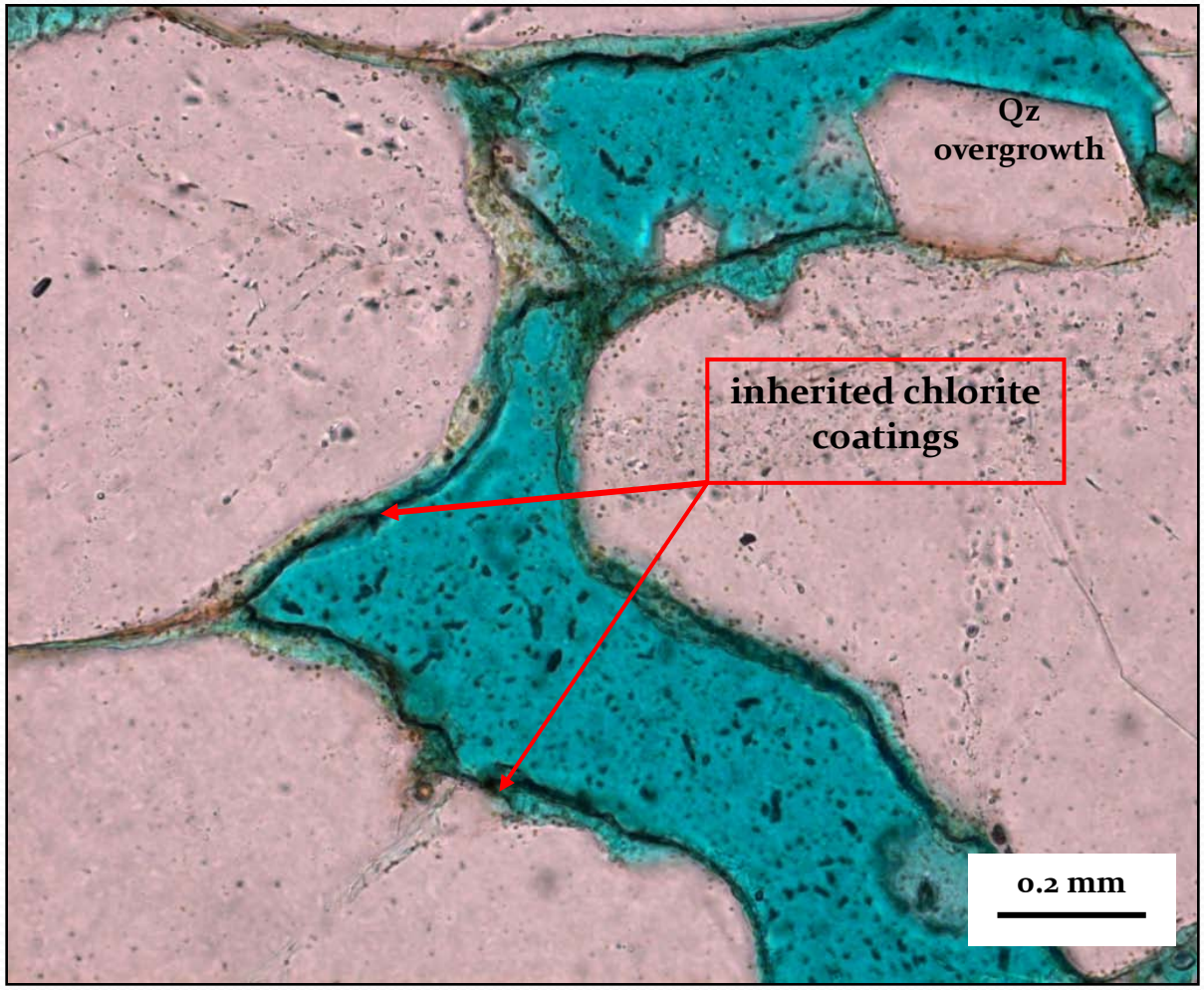
(Unayzah A)



Inherited Clay Type

Eolian Sand Sheet Facies

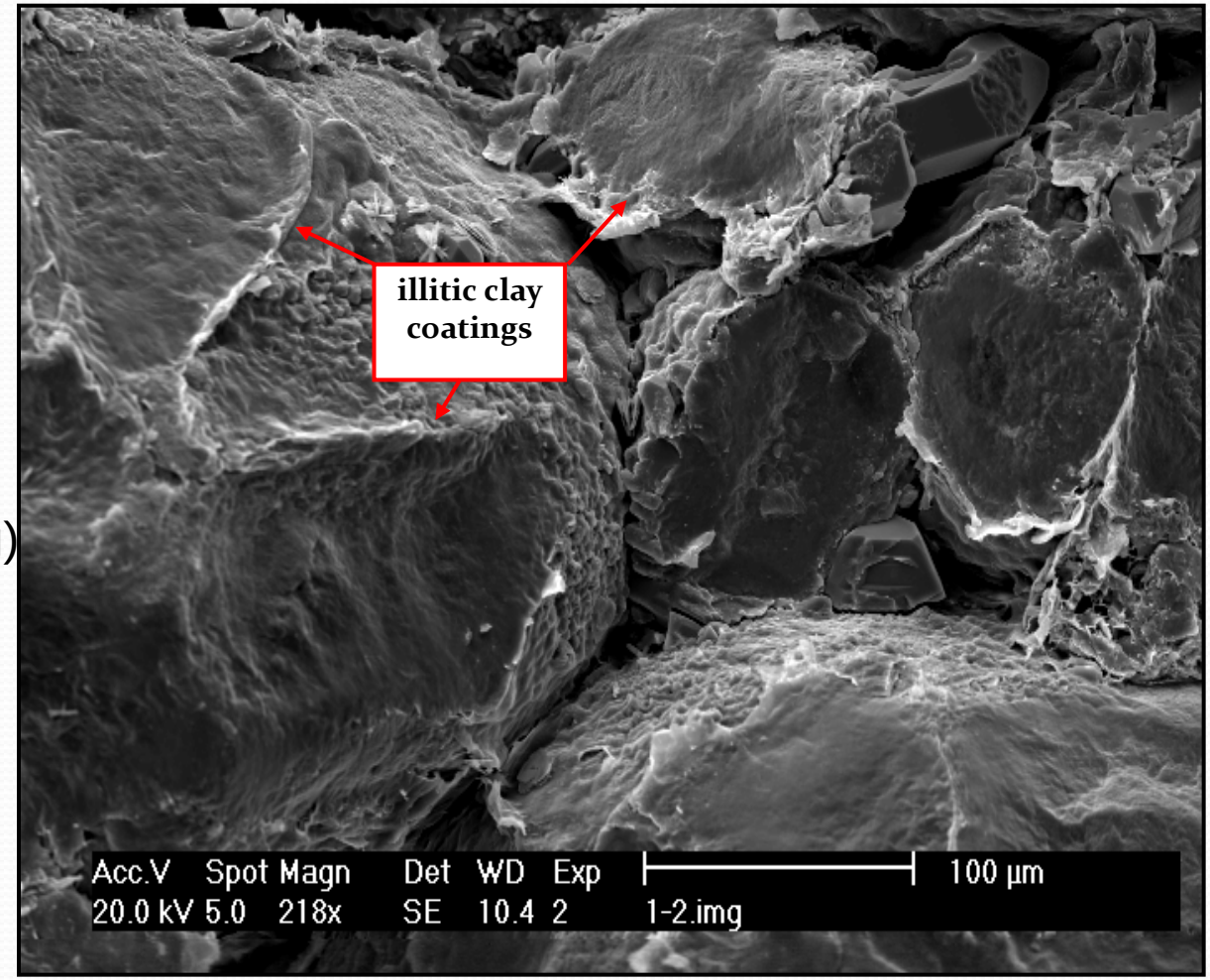
(Unayzah A)



Inherited Clay Type

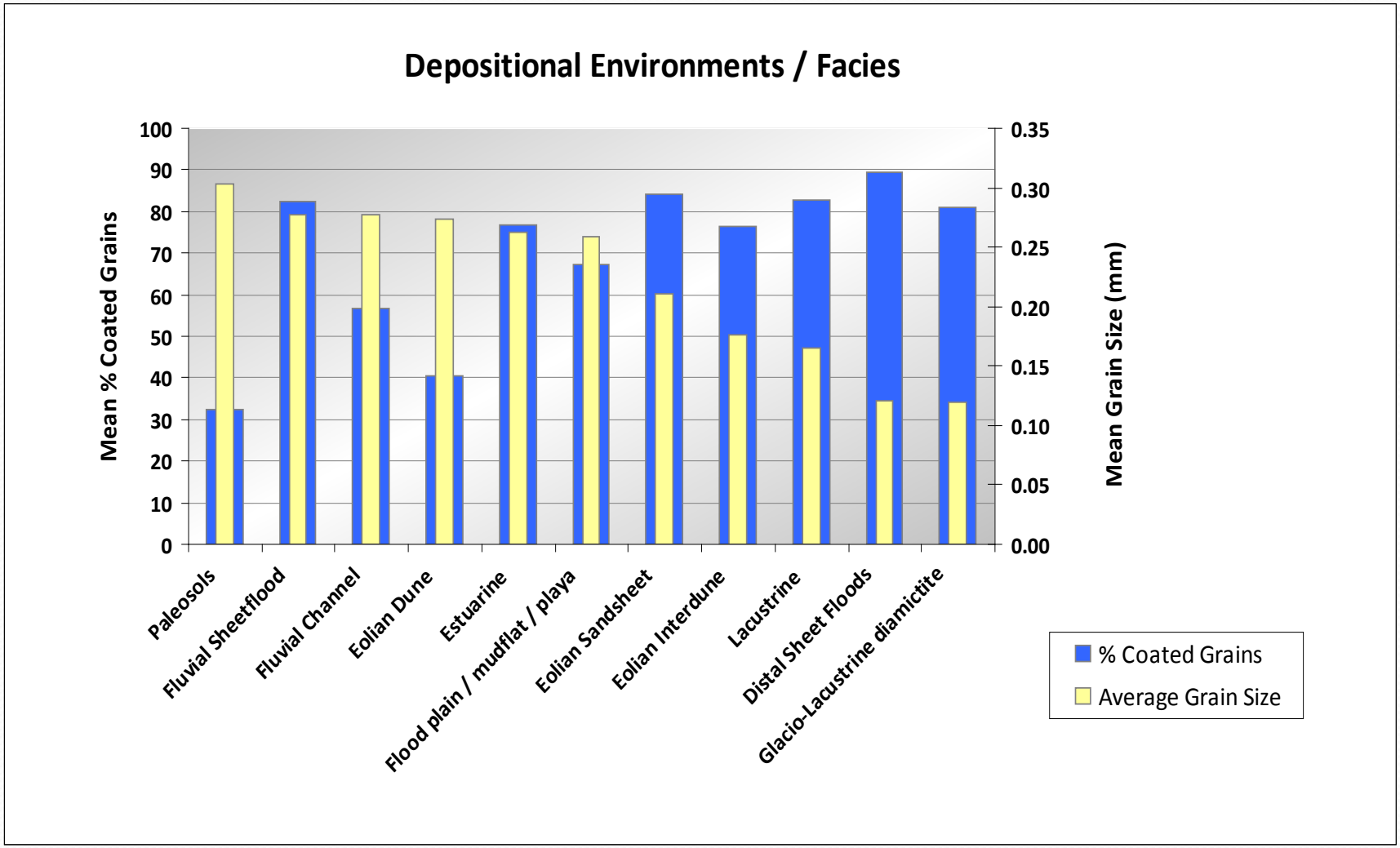
Eolian Sand Sheet Facies

(Unayzah A)

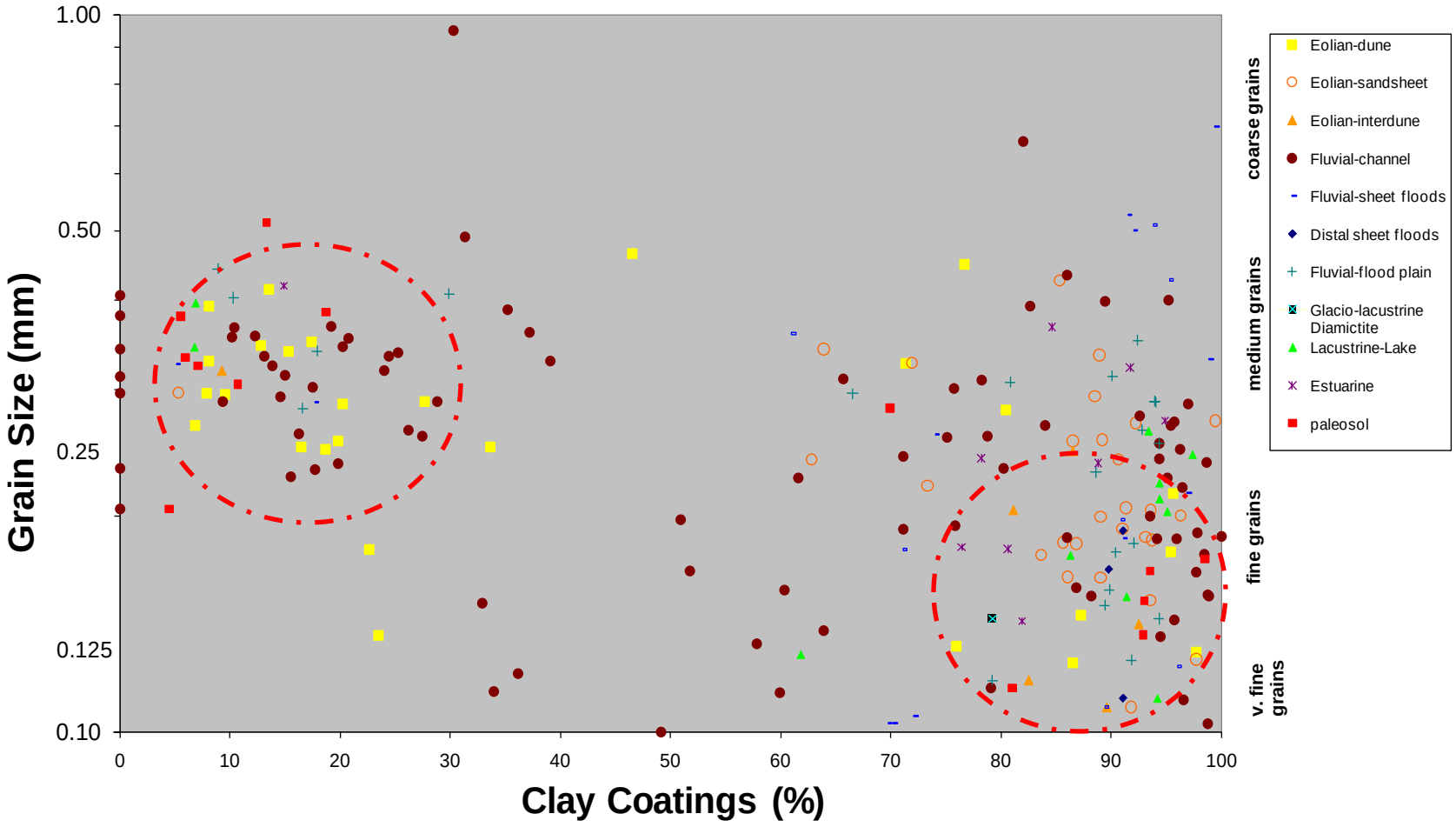


- Tangential (surface matting)
- At grain contacts

Petrographic Data

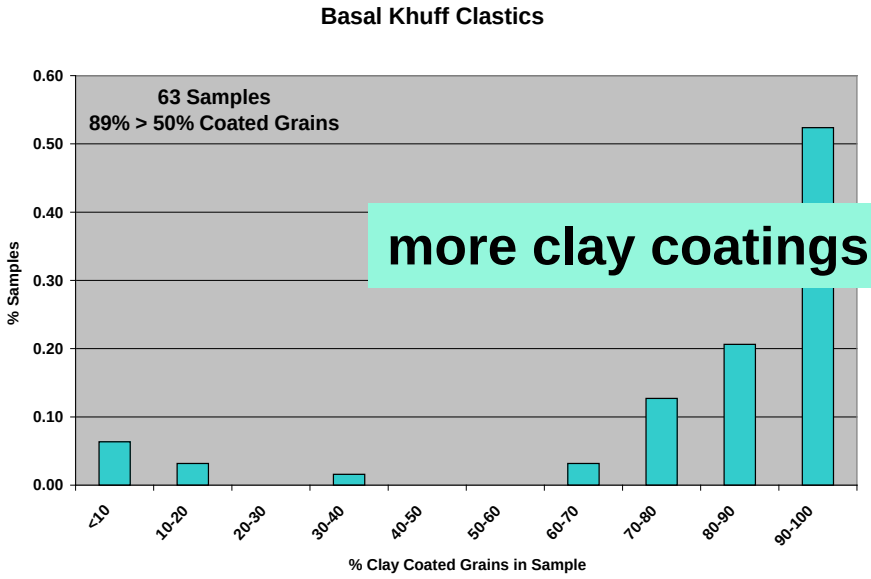


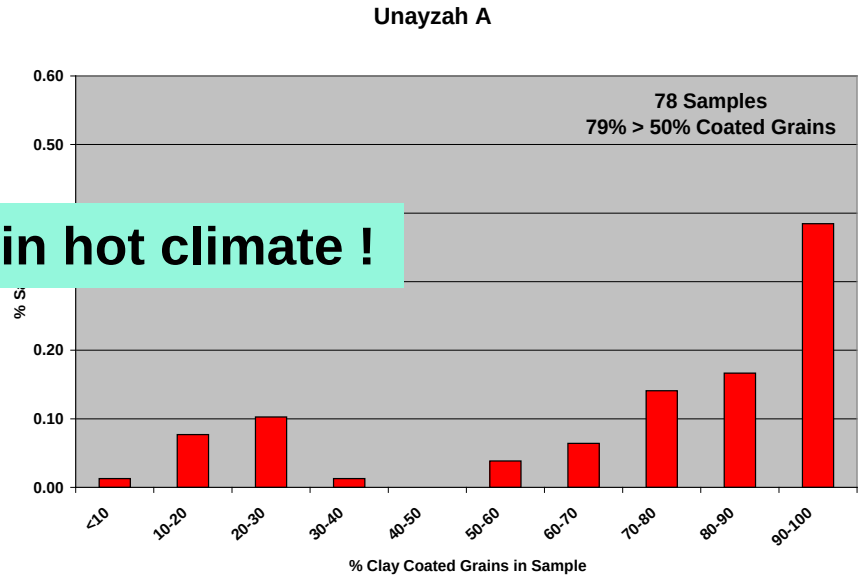
Petrographic Data



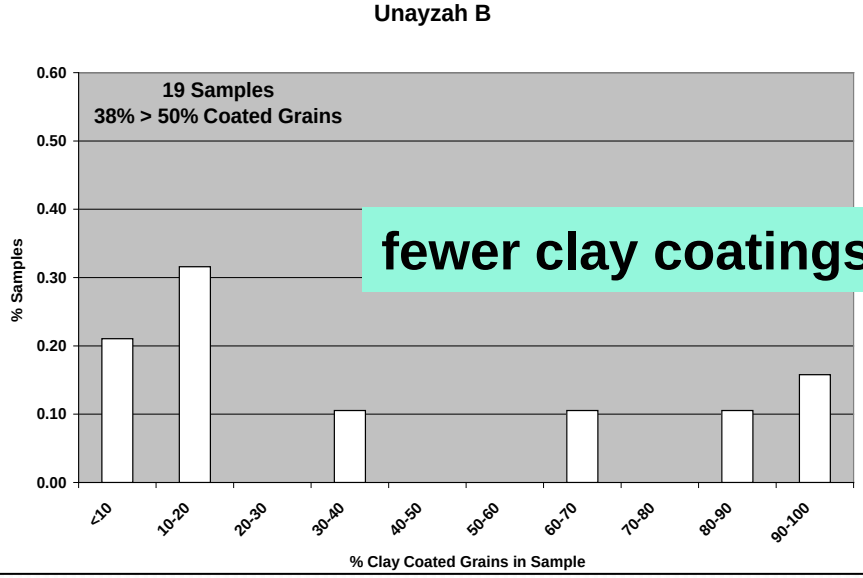
The % of clays coatings is grain size dependent!

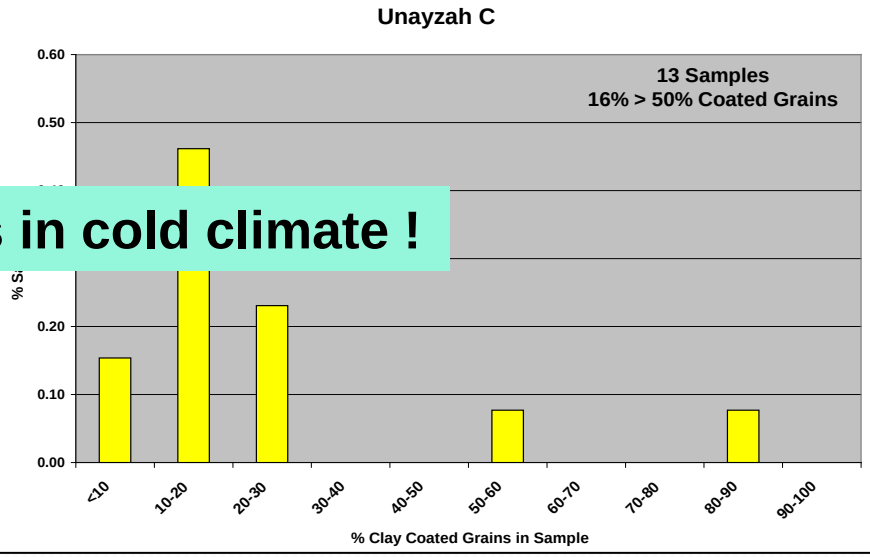
Found in ALL depositional environments!





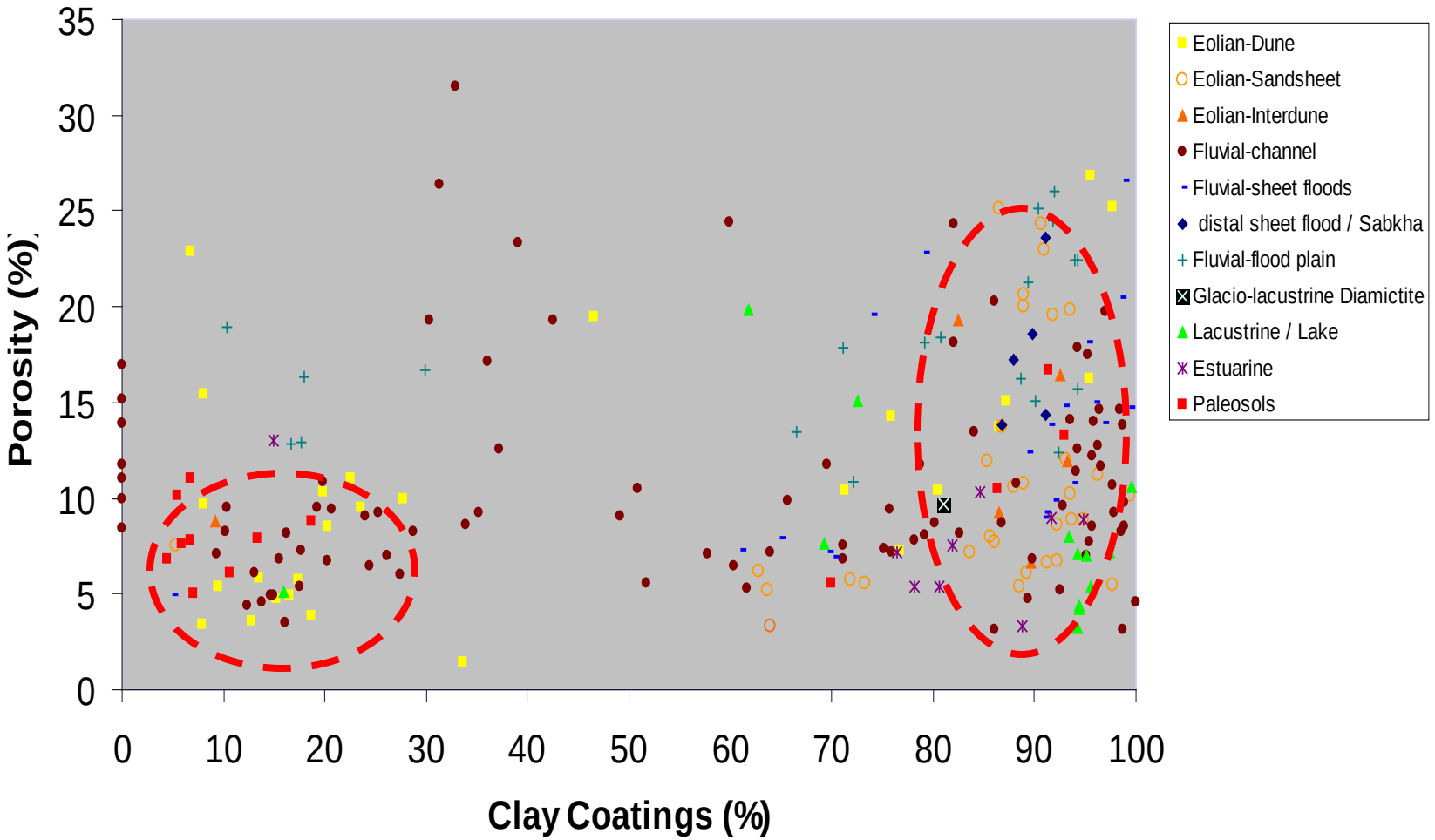
more clay coatings in hot climate !





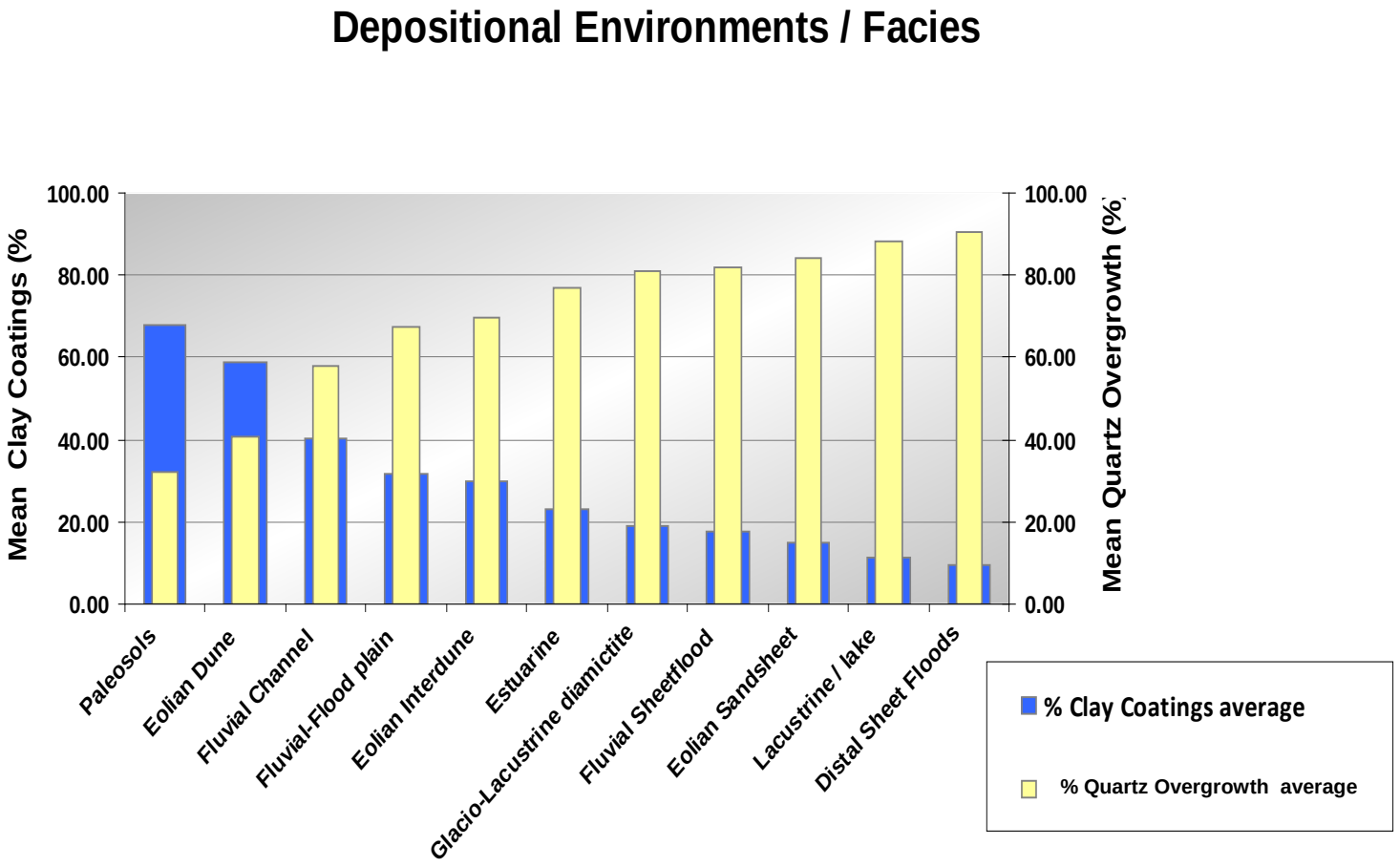
fewer clay coatings in cold climate !

Reservoir Quality



High porosity in samples with >90% clay coatings!

Reservoir Quality



Conclusion

- Clay coatings inhibit the formation of quartz overgrowths, hence help preserve porosity .
- Clay coatings are found in all depositional facies .
- Clay coatings are composed of illite and/or chlorite.
- The percentage of clay coatings depends on grain-size, depositional facies and stratigraphic position:
  - The finer the grains, the greater the clay coating. The coarser the grains, the less grain coating.
  - Clay coating mineralogy:
    - Mainly chlorite in eolian facies
    - Chlorite and/or illite in fluvial facies
    - Illite in fluvio-estuarine facies
  - Less clay coatings in Unayzah 'C' cold climate facies. More clay coating in Unayzah 'A' warm climate facies.